Search for a two-photon exchange contribution in inclusive DIS at HERMES

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Outline

1. HERMES at
2. inclusive DIS in
3. Two-photon exchange contributions
4. Search for

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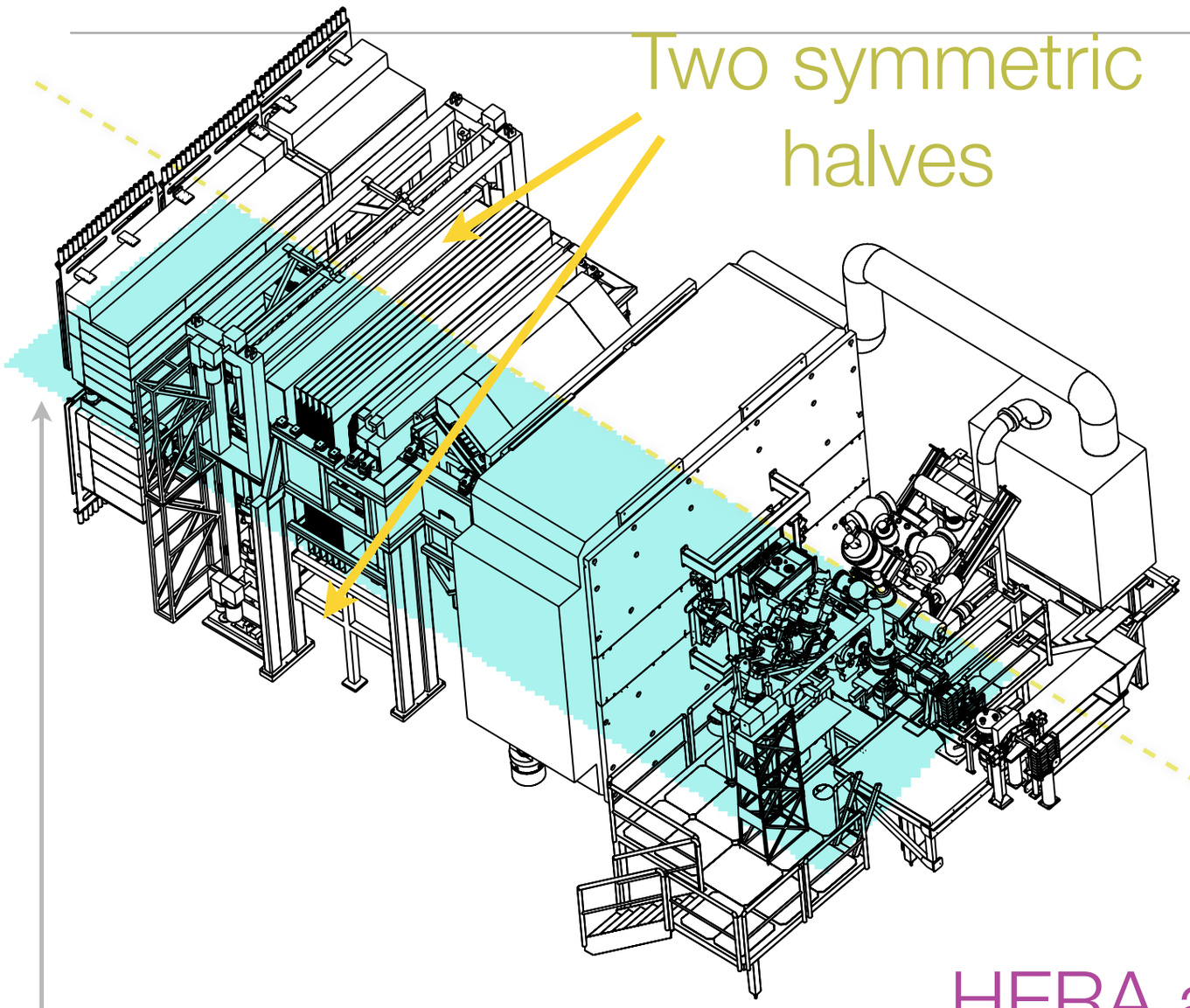
1. the HERMES experiment



- Forward spectrometer
- Fixed gas target:
  Transversely polarized H
- Target spin direction:
  reversed every 1-3 minutes
- Particle ID:
  TRD + RICH + calo + preshower

27.6 GeV
e-/e+ Beam

HERA accelerator
Hamburg

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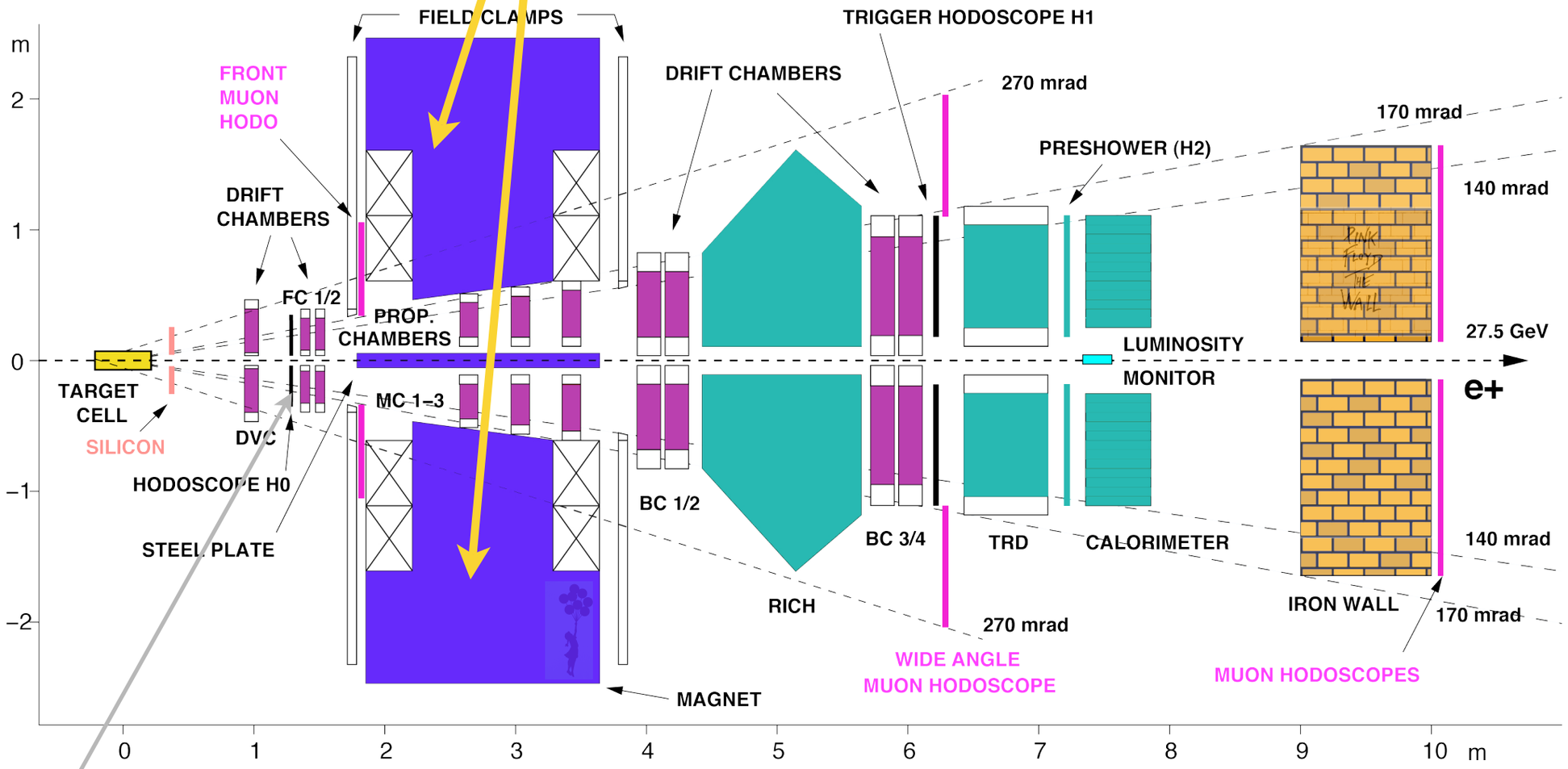
1. the HERMES experiment

Two symmetric halves



gap in the acceptance

HERA accelerator
Hamburg

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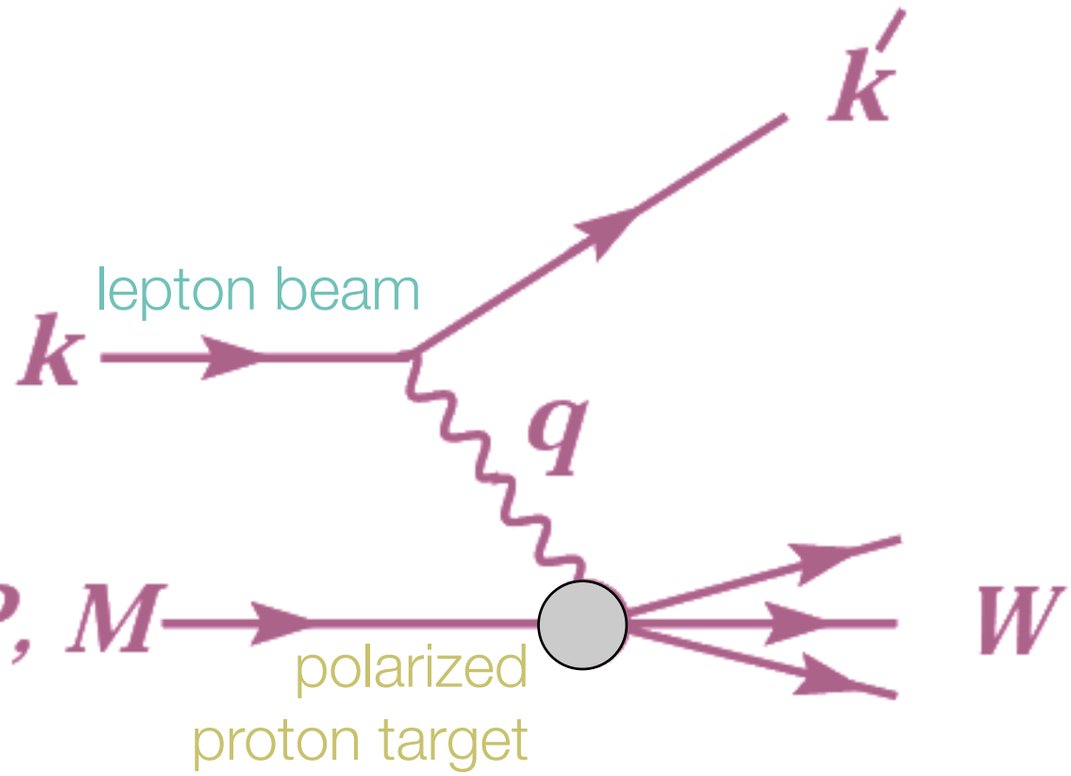
Deep Inelastic Scattering



described by

- $x_{Bjorken} = Q^2 / 2M(E-E')$
  fractional moment of the proton carried by the struck quark
- $Q^2 = -(k-k')^2$
  negative squared of momentum transfer q

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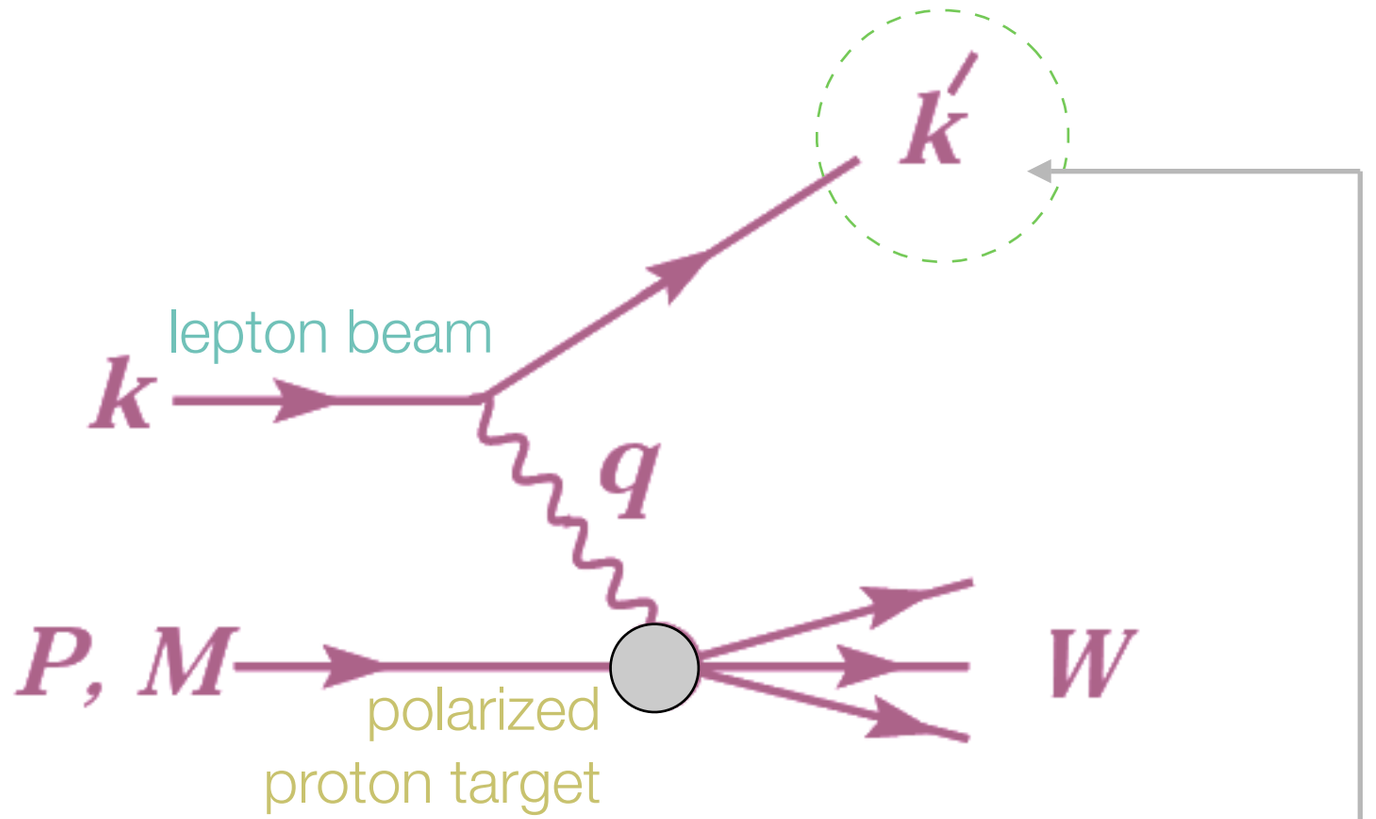
2. inclusive DIS

Deep Inelastic Scattering



Inclusive

only the scattered lepton is detected

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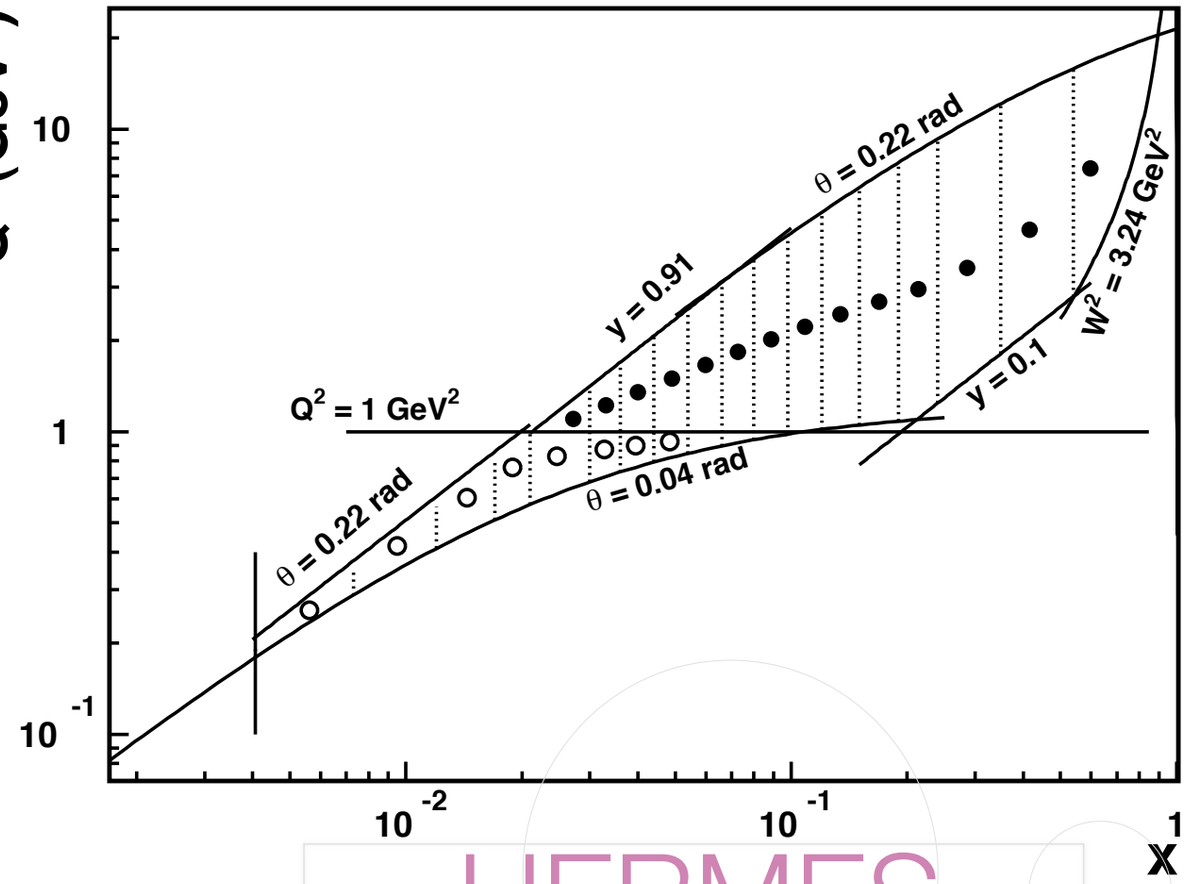
2. inclusive DIS

Deep Inelastic Scattering

kinematic plane



at HERMES

$0.004 < x_{Bjorken} < 0.9$

$0.1 < Q^2 < 20\ GeV^2$

$W^2 > 3.24\ GeV^2$

kinematic variables

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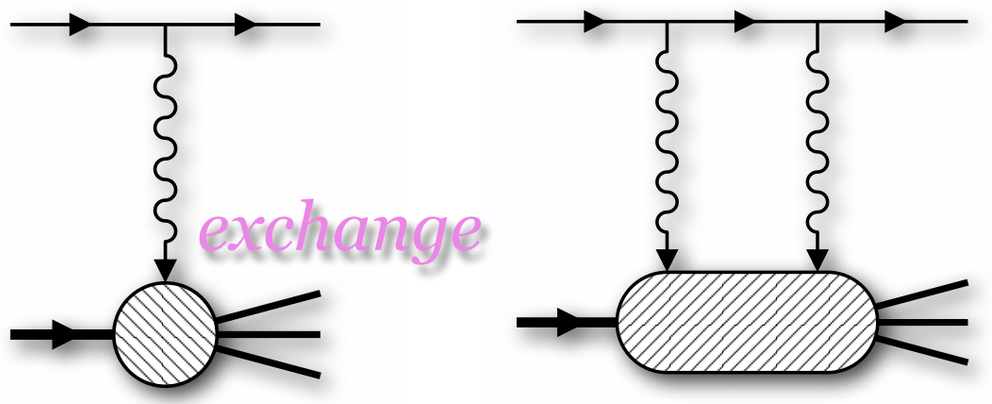
3. Two-photon exchange contributions

WHAT? is that

twoPhoton



onePhoton

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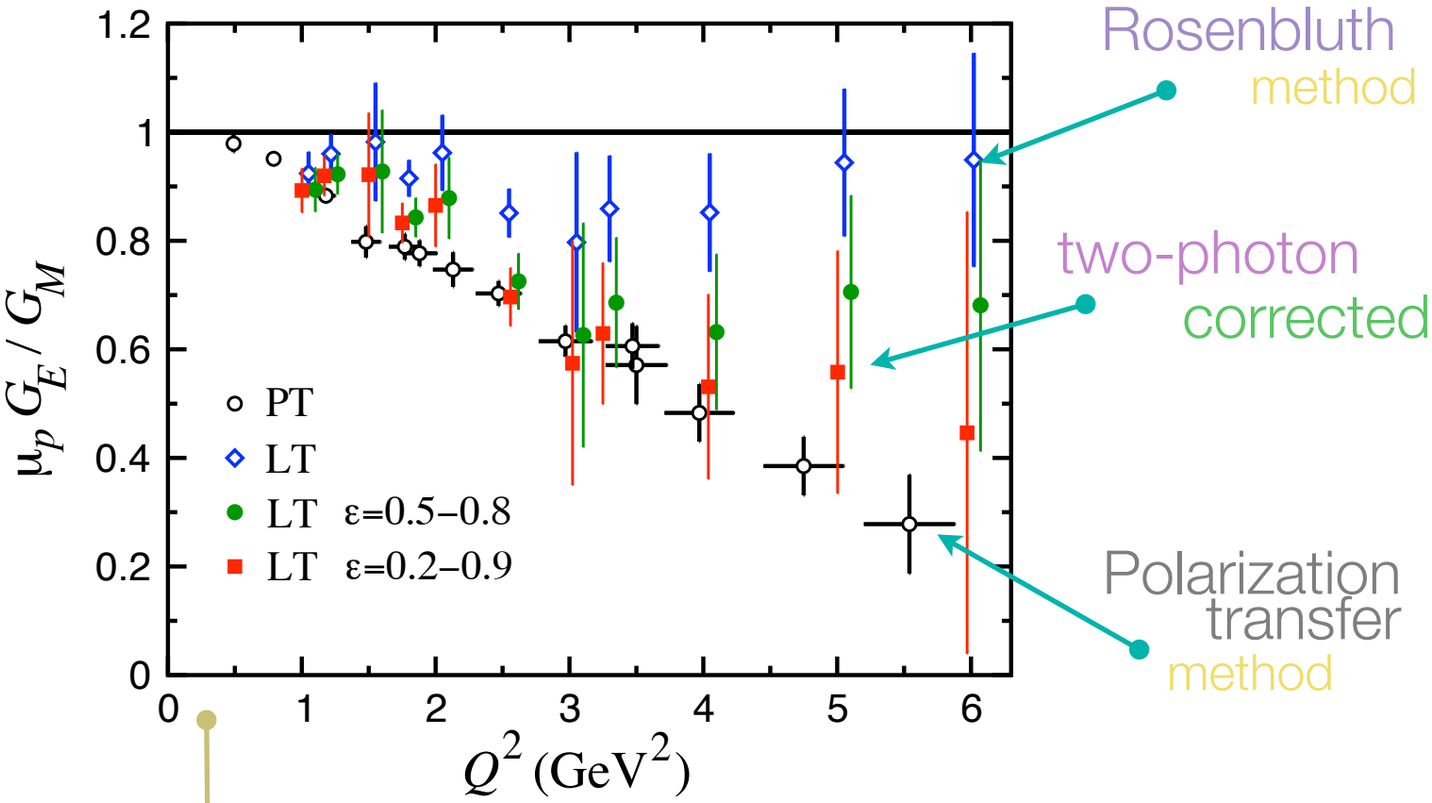
3. Two-photon exchange contributions

WHy ? is it interesting

> In recent years the two-photon-exchange cross section in electron nucleon scattering has received increased attention.
>
> In elastic ep scattering two photon effects are believed to be the best candidate to explain the discrepancy in the measurement of the ratio G_E/G_M of the electric and magnetic form factors of the proton obtained at large momentum transfer Q^2 using the Rosenbluth method and the polarization transfer method [1]. It was shown [2] that the interference between the one-photon and two-photon exchange amplitudes can affect the extraction done with the Rosenbluth method to a level of a few percent, enough to explain the discrepancy between the two methods.
>
> Two-photon exchange effects have also been shown [3] to play a role in the measurement of parity violation in elastic scattering of longitudinally polarized electrons on an unpolarized target. They can lead to corrections of several percent to the parity violating asymmetry.
>
> In inclusive Deep Inelastic Scattering (DIS) $l + N \rightarrow l' + X'$ two-photon exchange is expected to give rise to normal single spin asymmetries (SSA), which, in the 1-photon exchange approximation, are forbidden by the combination of time reversal invariance and parity conservation, and the hermiticity of the electromagnetic current operator, as stated in the Christ-Lee theorem [4].

example:

Ratio of proton form factors



from (P. G. Blunden, W. Melnitchouk, and J. A. Tjon, Phys. Rev. C 72 (2005) 034612)

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3. Two-photon exchange contributions

WHy ?
is it interesting

previous attemps of measurement

elastic scattering

$l + N \longrightarrow l' + N'$

non-ZERO asymmetries:

- SAMPLE
  S. P. Wells et al. (SAMPLE Collaboration), Phys. Rev. **C63**, 064001 (2001).
- PVA4
  F. E. Maas et al. (A4 Collaboration), Phys. Rev. Lett. **94**, 082001 (2005).
- G0
  D. S. Armstrong et al. (G0 Collaboration), Phys. Rev. Lett. **99**, 092301 (2007).

$\sim 10^{-5}$

transversely polarized e^-
off unpolarized protons

inelastic scattering

ZERO asymmetries:

- Cambridge Electron Accelerator
  J. A. Appel et al., Phys. Rev. **D1**, 1285 (1970).
  J. R. Chen et al., Phys. Rev. Lett. **21**, 1279 (1968).
- PVA4
  S. Rock et al., Phys. Rev. Lett. **24**, 748 (1970).

DIS ¿?

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3. Two-photon exchange contributions

How? can we measure it

theory:

Ref. [5] presents a theoretical treatment of the transverse SSA arising from the interference of one-photon and two-photon exchange amplitudes in DIS. With one particle polarized (beam or target) the spin dependent part of the cross section is given by:

$$\Delta\sigma \propto e_l \alpha_{em} \frac{m_{pol}}{Q} \varepsilon_{\mu\nu\rho\sigma} S^\mu p^\nu k^\rho k'^\sigma C_T.$$

- m_{pol}: mass of polarized particle
- e_l: charge of lepton
- C_T: twist-3 term arising from q-q and q-g-q correlations

*more on:

[5] A.Metz, M.Schlegel, and K.Goeke, Phys.Lett. **B643,** 319 (2006)

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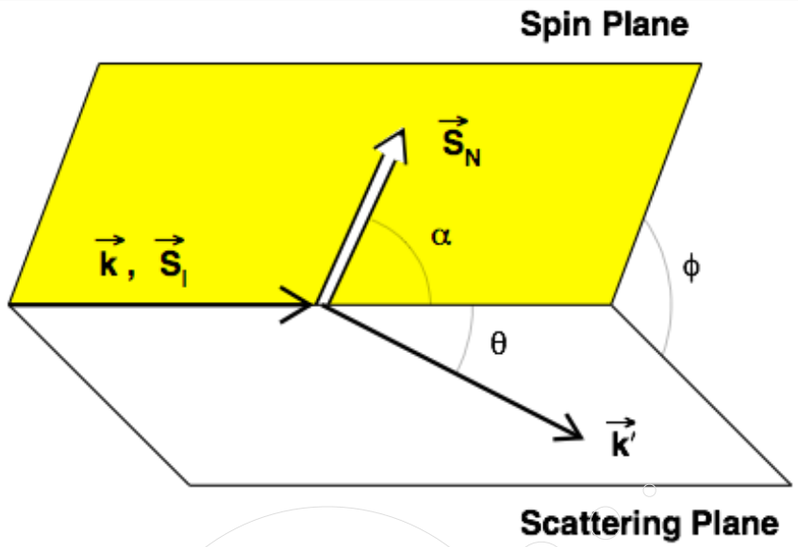
3. Two-photon exchange contributions

How?
can we measure it

theory:

$$\Delta\sigma \propto \vec{S}_N \cdot (\vec{k} \times \vec{k'})$$

effect is MAX when the scattered lepton is perpendicular to the transverse spin



interference of the one-photon and two-photon exchange amplitudes

→ inclusive Asymmetry left right

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3. Two-photon exchange contributions

How?
can we measure it

experimentally:

inclusive
Asymmetry
left right

$$A_N = \frac{N_R - N_L}{N_R + N_L}$$

expected

- order of magnitude ~ 10^{-4}
- change sign with beam charge e^-/e^+

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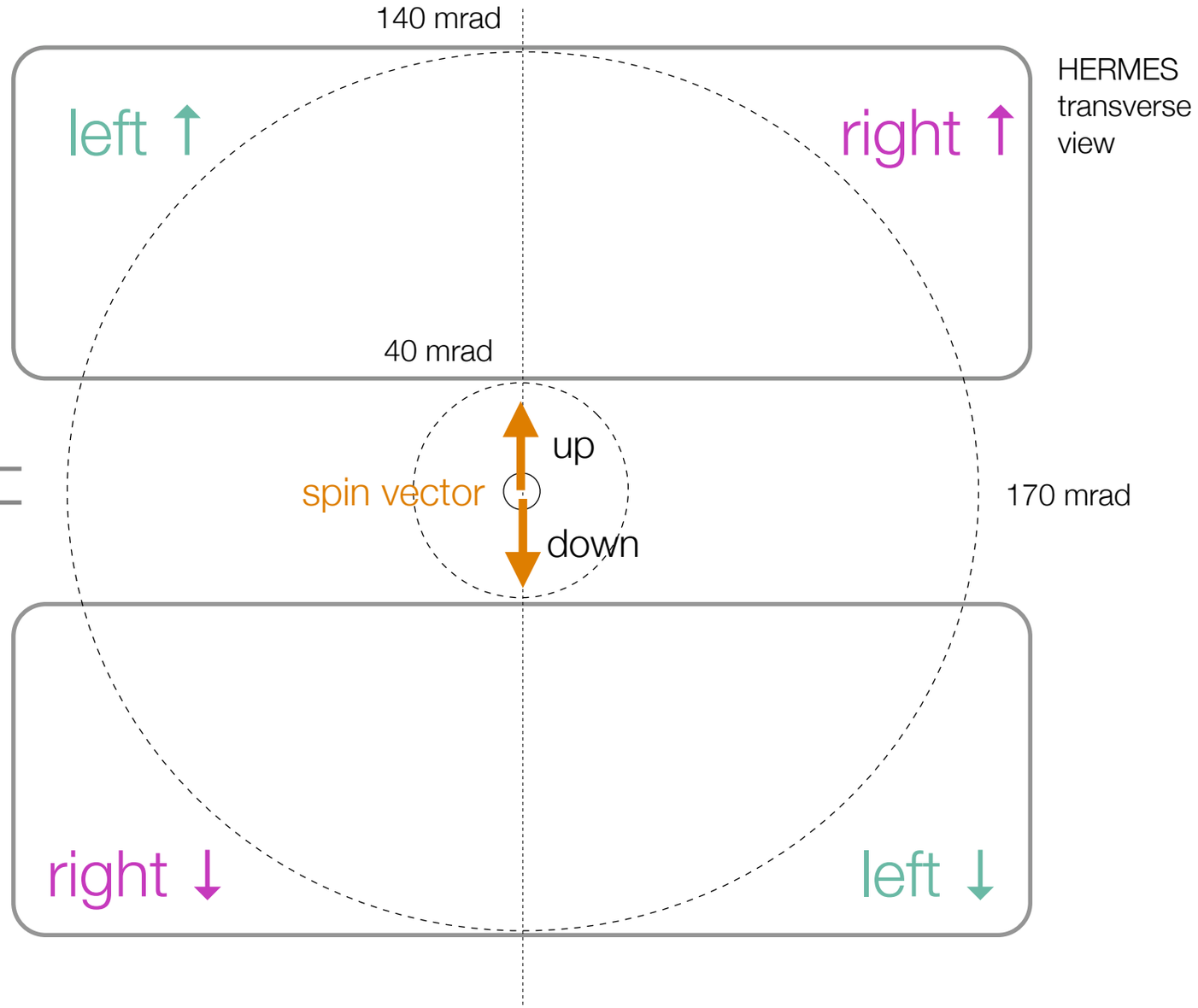
3. Two-photon exchange contributions

A note about acceptance:

acceptance gap

the highest sensitivity to a LR asymmetry is around the beam pipe. Since the HERMES acceptance doesn't cover this region, the asymmetry must be corrected for it



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3. Two-photon exchange contributions

How?
can we measure it

experimentally:

inclusive
Asymmetry
left right

$$A_N = \frac{N_R - N_L}{N_R + N_L}$$

measured asymmetry

$$A_N = \chi^{HERMES} \cdot A_N^{2\pi}$$

Asymmetry in full coverage

acceptance factor

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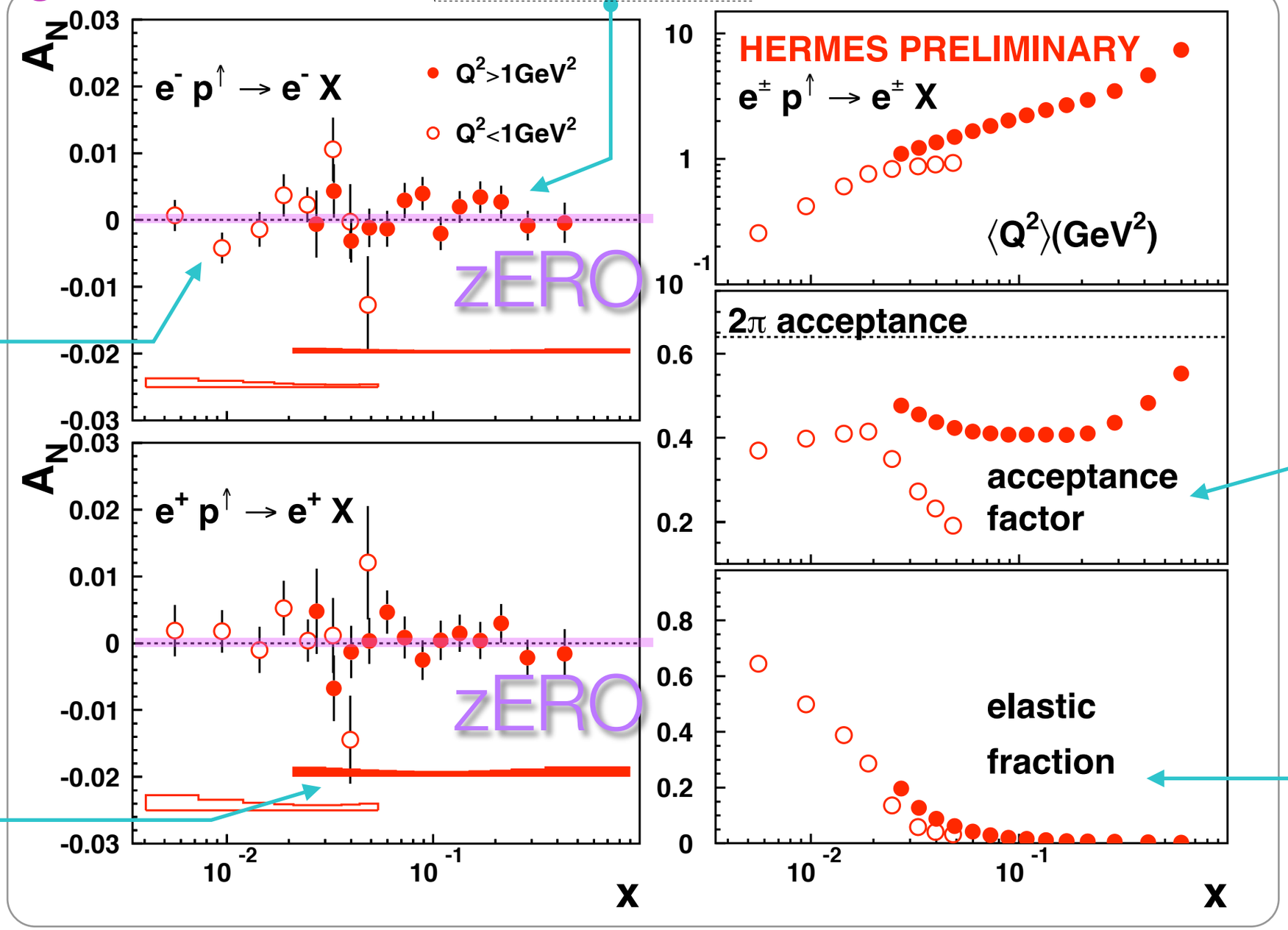
4. Results

inclusive
Asymmetry
left right

DIS region



low Q^2
interpretation not yet clear. but it might be useful

systematic error bands included trigger eff., PID, vertex reconstrc., and more

to calculate the asymmetry in 2π coverage, beyond HERMES acceptance

to estimate the contribution from elastic scattering at low x and Q^2

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Conclusions

- Inclusive single spin Asymmetries have been measured at HERMES on a transversely polarized proton target

- No evidence of two-photon exchange has been observed within the experimental uncertainties of the order of 10^{-3}

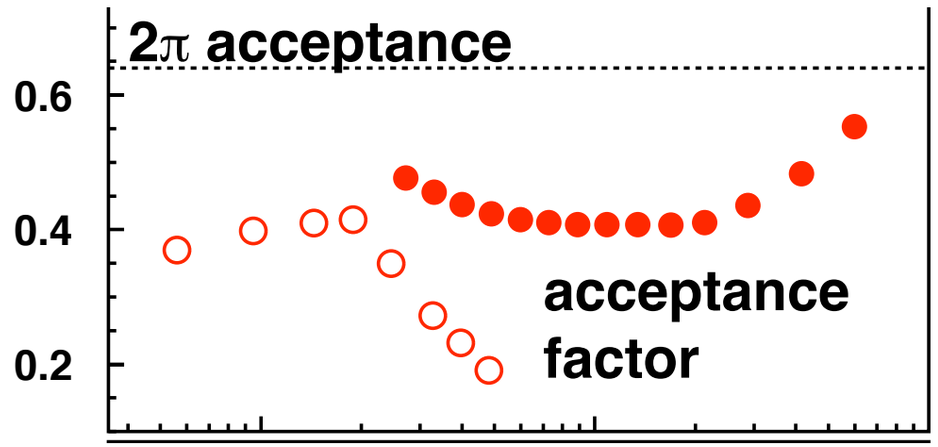
- This sets up the most precise limit on inclusive DIS up until now

Back-up slides

Back-up slides

A note about acceptance:

How?
to make this plot:



1. Implement "*false*" asymmetry $A^{\sin\Phi} \cdot \sin\Phi$ in MonteCarlo
2. Extract A_N as in real data for different values of $A^{\sin\Phi}$
3. since $A_N = \chi \cdot A^{\sin\Phi}$ → fit ratio $A_N / A^{\sin\Phi}$ to a line
4. Repeat step 3. for every (x, Q^2) bin

How?

can we measure it

another method:

$$A_{UT} = \frac{N_U - N_D}{N_U + N_D}$$

up down Asymmetry

$$A_N = \frac{N_R - N_L}{N_R + N_L}$$

left right Asymmetry

Back-up slides

How?

can we measure it

another method:

$$A_{UT} = \frac{N_U - N_D}{N_U + N_D}$$

Asymmetry

up down

target spin UP

target spin DOWN

transversely polarized target

unpolarized beam

Back-up slides

How?

can we measure it